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Sensitivity of Climate Variability to Anthropogenic and Natural Drivers during the Last Millennium

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Abstract: The degree and causes of climate variability during the last two millennia remain poorly understood. The interactions between forcings and intrinsic variability are complicated, and the proxy records of climate response are by definition indirect measures. An ensemble of millennial-length simulations with the Goddard Institute for Space Studies GCM (ModelE) is proposed to identify regional and temporal climate ―fingerprints‖ from potentially important forcing mechanisms. In addition, the model's Earth System components (chemistry, aerosols, water isotopes, and wetland methane emissions) will be included in time-slices of particular interest – such as the early medieval (MT, 1000-1200) or Maunder Minimum (MM, 1550-1750).

We propose a suite of coupled atmosphere-ocean model experiments from 850 AD to 1850. First, a simulation including solar, volcanic, orbital, and greenhouse-gas forcings, landuse changes, will be completed. This experiment will directly link in with other pre-Industrial experiments being completed as part of IPCC AR5 – using the same model and resolution as IPCC AR5 experiments – and it will be submitted to the PMIP3 last millennium program. Next, six ensembles of 5 members each will be performed to assess the relative impact of each of the climate forcings. Simulations include amplification of solar effects through a stratospheric ozone response. Global mean trends in surface temperature are expected to have a clear forced component, though internal variability will also have a large role, particularly at the regional scale. Previous work by this group (e.g., Shindell et al., 2001b; Shindell et al., 2004a) and data analyses have indicated that there may be a significant annular mode response to some forcings. The proposed experiments will be used to determine the magnitude of the predictable signal at regional scales over multi-centennial time periods.

Previously omitted additional forcing mechanisms will be addressed using shorter time-slice simulations with the online-tracer version of ModelE during contrasting climate periods (e.g. MM and MT), driven by saved ocean conditions from the transient experiments. Seven sets of experiments are proposed, including changes to dust, sea-salt, and ocean-derived sulfate, biomass burning ozone-precursors and aerosols, biogenic organic carbon, wetland methane emissions, and a final set with all components. These aerosol species are standard components in the model‘s 20th century simulations, so that we may compare millennial variability characteristics with those better constrained from more recent climate periods.

A singular value decomposition statistical technique will be applied to detect model regional and temporal variability patterns and compare with reconstructions of temperature from tree rings, ice core records, high-resolution ocean and lake sediment cores, speleothems, borehole inversions, and corals. Model variability (within and across time-slices) of polar concentrations of aerosol/gaseous species

will be compared with ice core records of dust, sea salt, BC, sulfate, methanosulfonic acid, methane and water isotopes.

This project will allow identification, comparison and improved quantification of major climate forcings. Comparison of model and proxy records will test model-simulated mechanisms while the model in turn provides insight into factors contributing to proxy variability. The addition of potentially important forcing mechanisms will enable a more comprehensive evaluation of the climate sensitivity.